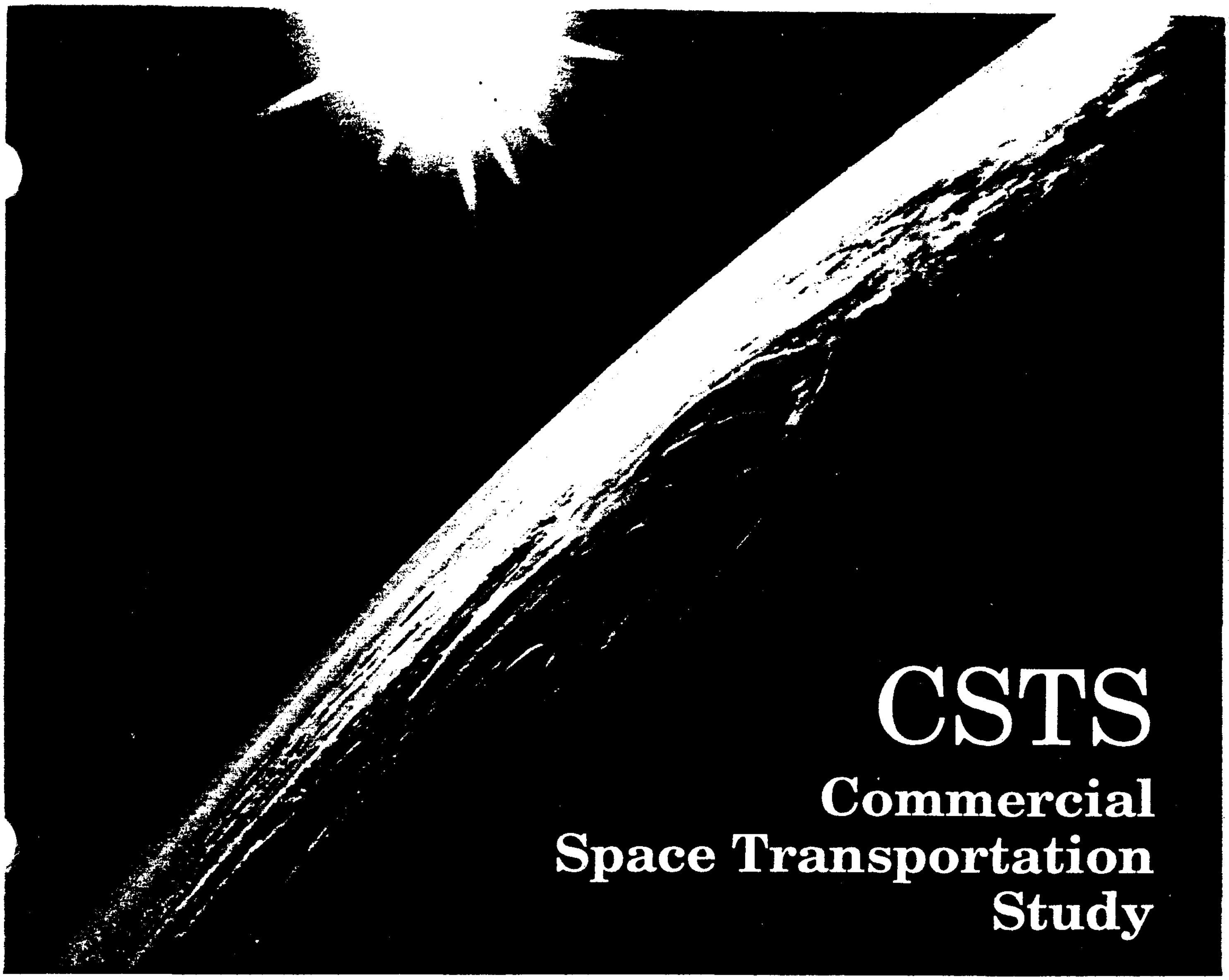

CSTS
Commercial Space Transportation Study

April 1994

Executive Summary

Boeing General Dynamics Lockheed

Martin Marietta McDonnell Douglas Rockwell

APRIL 1994

THE COMMERCIAL SPACE TRANSPORTATION STUDY

Executive Summary

THE CSTS ALLIANCE

Boeing

General Dynamics

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McDonnell Douglas

Rockwell

PREFACE

This document provides an executive summary of the Commercial Space Transportation Study (CSTS) Phase I activities, which consisted of a survey and business assessment of existing, emerging, and potential new space markets. The CSTS Alliance conducted this study as a precursor to defining technology requirements and system concepts for a new commercial space transportation system; it took place over a period of 11 months (June 1993 through April 1994). The detailed study results may be requested from the NASA Langley Research Center, Hampton, VA, which provided overall study guidance and coordination.

The Phase I study results indicate that new markets will emerge when launch costs are significantly decreased. Additionally, the forecasted growth in these markets appears to be substantial as access to space becomes service oriented and economically feasible to the business community. However, the market elasticity does not appear to be sufficient to support a purely commercial investment (on the part of Industry), with a reasonable payback in a reasonable period of time, under current ways of doing business. More innovative arrangements between Industry and Government must result if a new space transportation system is to emerge in the near future.

The Commercial Space Transportation Study Alliance was composed of members from the following six major United States Aerospace Corporation components; their study efforts were performed under the contracts noted below.

Boeing Defense and Space Group (NAS1–19247, Task 14)
General Dynamics Space Systems Division (NAS1–19242, Task 9)
Lockheed Missiles and Space Company, Inc. (NAS1–19241, Task 27)
Martin Marietta Astronautics (NAS1–18230, Task 9)
McDonnell Douglas Aerospace (NAS1–19244, Task 14)
Rockwell Space Systems Division (NAS1–19243, Task 12)

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Section 1
INTRODUCTION

1.1 THE BIRTH OF THE COMMERCIAL SPACE TRANSPORTATION STUDY

It is commonly recognized that the US space launch industry needs revitalization to recapture commercial markets from foreign competition and to stimulate the development of new commercial ventures in space. To this end, representatives of six aerospace companies (Boeing, General Dynamics, Lockheed, Martin Marietta, McDonnell Douglas, and Rockwell) and NASA met in March 1993 at NASA's Langley Research Center (LaRC) to discuss means by which a new commercial space transportation system might be developed.

A perception is held by government and industry that a new, state-of-the-art launch system can provide an order of magnitude reduction in launch costs and that a reduction of that magnitude will cause the equivalent of a space industrial revolution with a substantial increase in users and traffic. The group meeting at NASA LaRC concluded that to become economically viable, a new launch system must generate new commercial markets. This group, now known as the Commercial Space Transportation Study (CSTS) Alliance, established the need for a market exploration study to identify potential customers, determine price elasticity of demand, and assess the commercial business opportunities for such a future launch system. This plan was briefed to the NASA Administrator Dan Goldin on 30 April, and in May the partnership between NASA and the Alliance began.

The CSTS objectives (Figure 1-1) were to assess market elasticity with the long-term goal to expand the market for space products and services. Significant results of the Phase 1 CSTS effort, performed between June 1993 and April 1994, are summarized in this document.

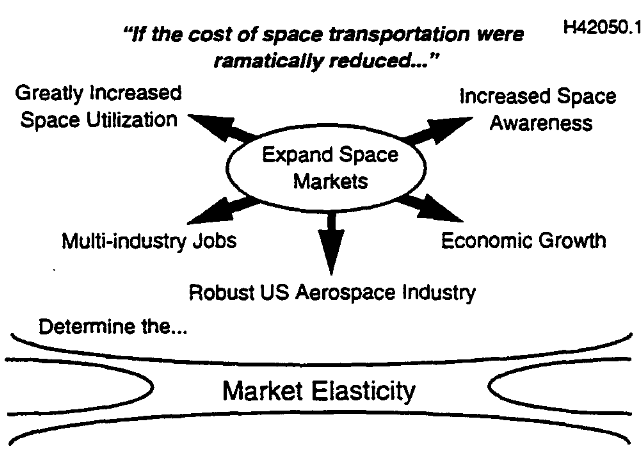

Figure 1-1. CSTS Objectives

1.2 STUDY APPROACH AND METHODOLOGY

The CSTS approach was different from traditional studies, as is summarized in Table 1-1. First, six normally competitive aerospace companies worked together as an Alliance to accomplish the objectives of the study. Second, this study concentrated on potential customer needs rather than starting with a preconceived solution of a transportation system and then trying to identify customers for it.

Table 1-1. Why the CSTS Approach Is Different

CSTS approach	Classical approach
■ Focus on market thresholds and market elasticity	■ Focus on vehicle concepts
■ Create the market addressing both traditional and non-traditional customers	■ Survey the market
■ Create opportunities	■ Identify needs
■ Contractors working together	■ Contractors compete
■ Government supported technology; commercially supported development and operation	■ Government funded and operated
■ Economic growth from government and commercial investment, and financial returns	■ Economic growth from government investment
■ Focus on economic return	■ Vehicle performance driven

The CSTS market assessment followed two paths. Key decision makers within a broad range of industries who might have future business activities in space were contacted. These contacts spanned a wide spectrum of industry, including advertising, electronics, energy, entertainment, health care, manufacturing, telecommunications, tourism, and academia.

In parallel, a business analysis effort assessed the opportunities using analytical business models to validate the data from the market surveys and to test assumptions about the new markets. Interview findings identified new commercial space markets, additional characteristics of the markets, key decision factors from an "insider's" perspective, and space transportation system attributes necessary to meet commercial user needs. Market area revenues and capture opportunities were then quantified. These contracted CSTS tasks, identified in Figure 1-2, were augmented by additional efforts performed by the Alliance using company discretionary resources (shaded boxes).

For each market area, a range of projected demand was identified—high, medium, and low probability. High probability projections represented the lowest market risk and produced the lowest estimate of future transportation demand. Business ventures included in

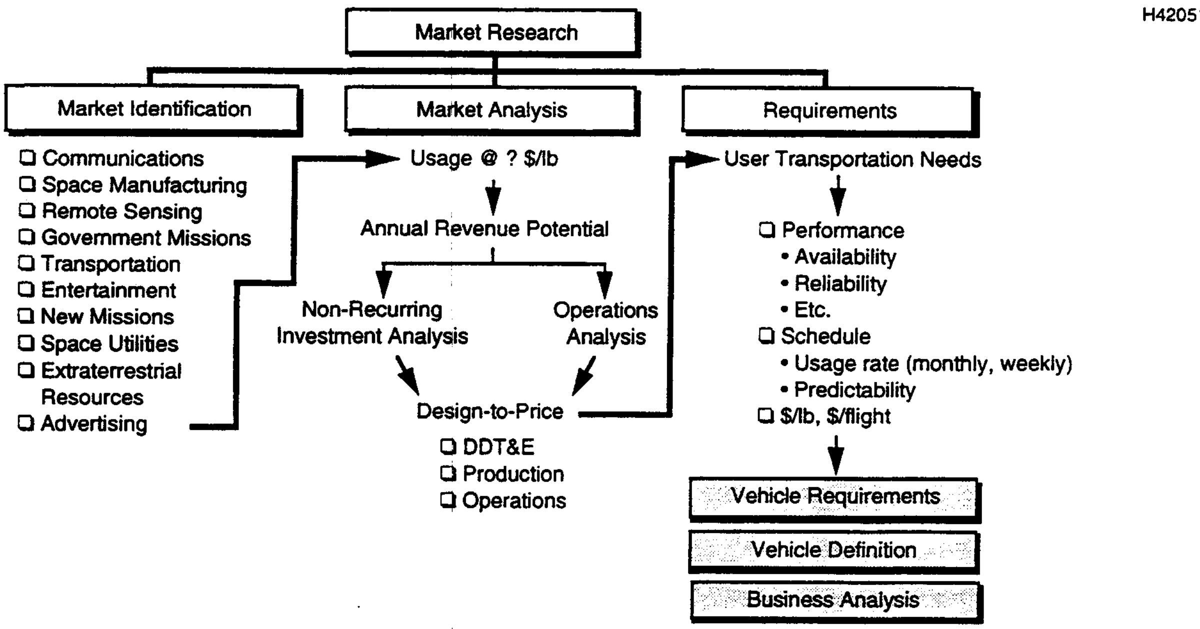

Figure 1-2. CSTS Approach and Methodology

these projections fall within current business operating conditions and meet market area financial projections. In contrast, the low probability demand projection allowed optimistic extrapolations and expansions of current business activities into space, with business activities still within current market area financial projections, and acceptable market area rates of return. The medium probability demand model was a nominal extrapolation between the low and high probability markets.

Section 2
MARKET DEFINITION

The current utilization of space is predominately government sponsored scientific research and military applications. Commercial space activities are driven by the communications satellite market, with other markets emerging but small in comparison. Figure 2-1 illustrates the current market focus.

2.1 NEW MARKET AREA IDENTIFICATION

CSTS Market identification covered a spectrum of potential opportunities. Our imagination stretched beyond traditional markets, from space manufacturing to space tourism/entertainment, to law enforcement and space burial. As illustrated in Figure 2-2, 114 market areas were identified; these were narrowed to 57 markets considered to have significant business potential. A summary of these markets is shown in Figure 2-3. No market was dismissed until a cursory understanding of the business opportunity and potential market solution had been achieved. Through continual interaction with "ownership" industries, we identified four key business ventures that could be used as the foundation of CSTS.

2.2 MARKET AREA EVALUATION AND SELECTION METHODOLOGY

Evaluation of each market area focused upon four critical questions:

- Is there a credible, sustainable market? (i.e., identify markets and potential users).
- Is the market solution technically feasible?
- Are the business risks acceptable? (i.e., evaluate elasticity of demand)
- Will there be a sufficient, committed market to drive a new transportation system?

Markets that did not meet the minimum criteria, market potential, and/or technical feasibility were subsequently deemphasized. The business outlook was further developed for the remaining markets. Markets identified as viable but not large enough individually to sustain a new transportation system were combined to form multifunctional elements, such as the space business park.

2.3 DESCRIPTION OF MOST PROMISING MARKET AREAS

After extensive market research and analysis, four market areas were identified to be the major drivers for a new commercial space transportation system: communications, government missions, hazardous waste disposal, and space business park. Each is highlighted in Figure 2-3, and discussed in further detail in the following paragraphs.

2.3.1 Communications Market Area

Today there are approximately 125 active communications satellites operating in geostationary orbit to serve the television and telephone industry. In addition, new applications are continuously emerging which will place new emphasis on the satellite. Over the last decade both business and homes have started to access satellites directly. Today, for example, the financial community transfers about $300 trillion per year, and airlines transmit and receive reservation information directly to and from satellites. Cable programmers use satellite communications to feed cable companies as many as 100 channel selections. In Japan and Europe, homes are receiving television and radio directly from satellites; the United States is about to obtain the same operational capability. Worldwide direct broadcasting will allow anyone with a small dish antenna to receive given TV and radio stations regardless of their location. Remote and developing areas around the world will be able to inexpensively offer

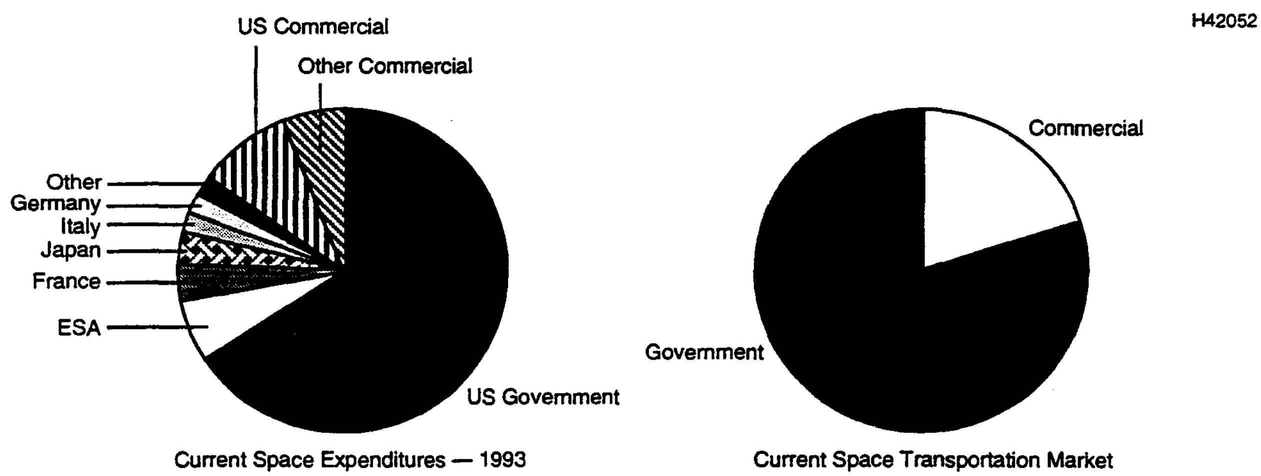

Figure 2-1. Current Space Utilization

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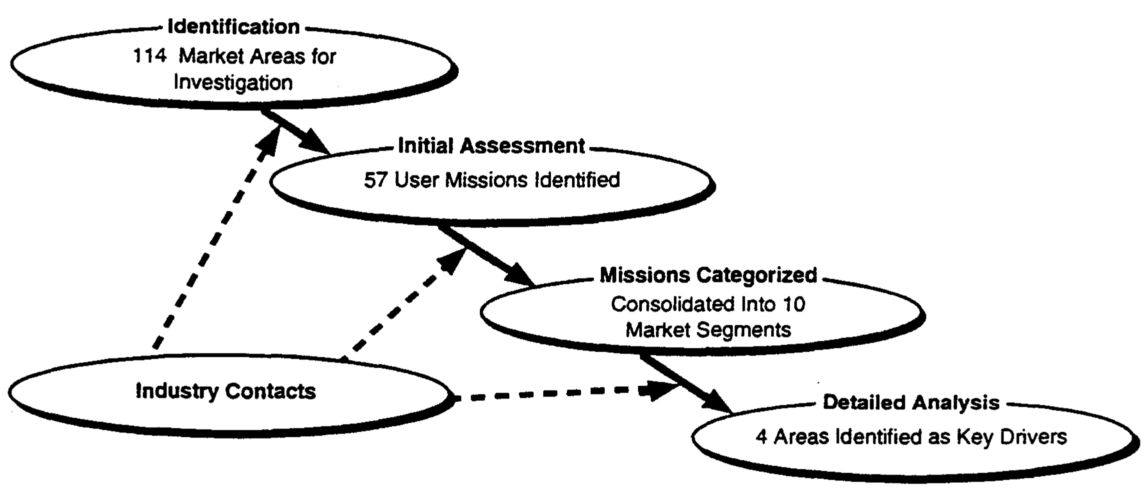

Figure 2-2. Systematic Evaluation of Market Areas

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Communications
- Survey and Locate
- Telecommunications
- Direct Broadcasting
- Global Digital Data Trans
- Global Positioning
- Remote Area Education
- Global Air Traffic Management
- GEO Platforms
- Mobile Communications

Government Missions
- Government Missions
- Treaty Verification
- Increased ISSA Missions
- Law Enforcement
- Human Planetary Exploration
- Asteroid Detection/Negation
- Emerging Nation Missions
- Space Science
- Space Test Bed

Transportation
- Space Rescue
- Fast Package Delivery
- Space Servicing & Transfer
- Hazardous Waste Disposal
- Space Tourism
- Ultra HSCT

New Missions
- Space Debris Management
- Space Medical Facilities
- Space Hospital
- Space Settlements
- Space Agriculture
- Space Business Part

Remote Sensing
- Remote Sensing
- Weather Observation
- Geography Info Services
- Personal Earth/Space Viewing
- Weather Forecast and Mod
- International News Observation and Reporting
- Upper Atmosphere Exploration
- Real-Time Surveillance

Space Manufacturing
- Space Manufacturing
- Space Science Research
- Microgravity Processing
- Academia Research
- Biological Prod/Laboratories
- R&D Facilities
- Space Robotics

Extraterrestrial Resources
- Lunar LOX and He3
- Extraterrestrial Resources

Entertainment
- Digital Movie Satellites
- Orbiting Movie Studio
- Space Athletic Events
- Artificial Space Phenomena
- Space Theme Park

Advertising
- Novelties
- Space Advertisement/ Orbiting Billboards
- Space Product Demo
- Space Burial

Space Utilities
- Space Solar Power

☐ = Areas Showing Most Promise

Figure 2-3. CSTS Market Analysis Identified 57 Prospective User Missions, and Four Major Space Transportation System Drivers

quality education to their population. The Navstar Global Positioning System (GPS) is allowing people anywhere on the globe to instantaneously locate their position within 100 meters.

By 1998 cellular telephone users will be able to talk via satellite from anywhere to anyone. This capability will assist the business people in the developed world, as well as allow for undeveloped nations to quickly establish telephone service. This expansion of services will continue to fuel the satellite market. By the early 2000s, satellite communication revenue should top $40 billion, with a corresponding growth in the number of communication satellites. Figure 2-4 shows the projected numbers of satellites required to meet this growing market demand for the medium probability projection.

2.3.2 Government Missions

The government missions category has three primary market segments: (1) existing government missions; (2) increased space station missions; and (3) space science. Government missions end users are normally government entities that can provide a stable business base for the launch market.

Existing government missions are the continuation of traditional government chartered space activities with little change. Payload events are not anticipated to grow because of budget limitations. They will be

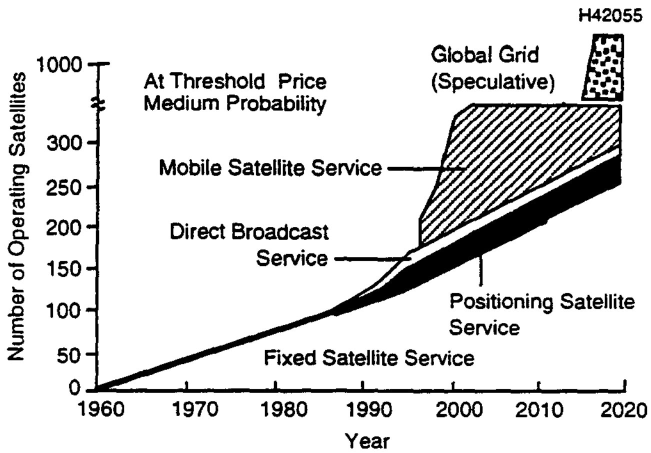

Figure 2-4. Communications Market Growth Projection

relatively constant, across time and market probability, at the near-term projections, with payloads ranging from less than 1,000 lb to 40,000 lb.

Increased space station missions consists of logistics support to the International Space Station Alpha (ISSA). It is expected that most applications fall within the area of experiments in various scientific fields, technology development for commercial and other uses, as well as crew rotation. Increased flights over the baseline of seven per year at 25,000 lb are based upon reinvestment of a portion of the launch cost savings (between 0% to 80% depending upon the market probability).

Space science consists of all missions conducted to expand knowledge of the universe. These missions include astronomy, robotic planetary exploration, and space physics and range from less than 1,000 lb to 40,000 lb. Increased flights over the current projections are based upon the reinvestment of launch cost savings relative to a $1 billion to $3 billion space science budget (depending upon the market probability).

Figure 2-5 summarizes the elasticity of the government missions market. In general, it appears that it is possible for the market to increase if a sufficient reduction in launch costs is achieved. This is true for both an increase in the number of payload events and an increase in mass to orbit.

2.3.3 Hazardous Waste Disposal

By the year 2000 there will be an estimated 51,000 metric tons of high-level nuclear waste in the US. Spent reactor fuel is accumulating at the rate of 1,000 tons per year, storage pools at the power plants are already full, and there is no permanent storage facility in this country.

The Department of Energy (DOE) plans to spend $43 billion over 30 years for two permanent waste repositories—Yucca Mountain, Nevada, and an as yet unidentified site in the eastern United States. However, public opinion is against having nuclear waste permanently stored underground because safety is difficult to guarantee for tens of thousands of years. Local communities especially fear degradation of safe storage due to seismic activity or contamination by running water. This has become a significant environmental concern; permanent ground storage of nuclear waste might already be a politically and socially unacceptable solution in the United States.

Space disposal of concentrated nuclear waste is technically feasible, requiring no new technology development. Our assessment shows it to be cost-effective compared with permanent ground disposal. There are several options for space disposal. We selected as our costed option for this study the following: simple chemical separation, use of existing

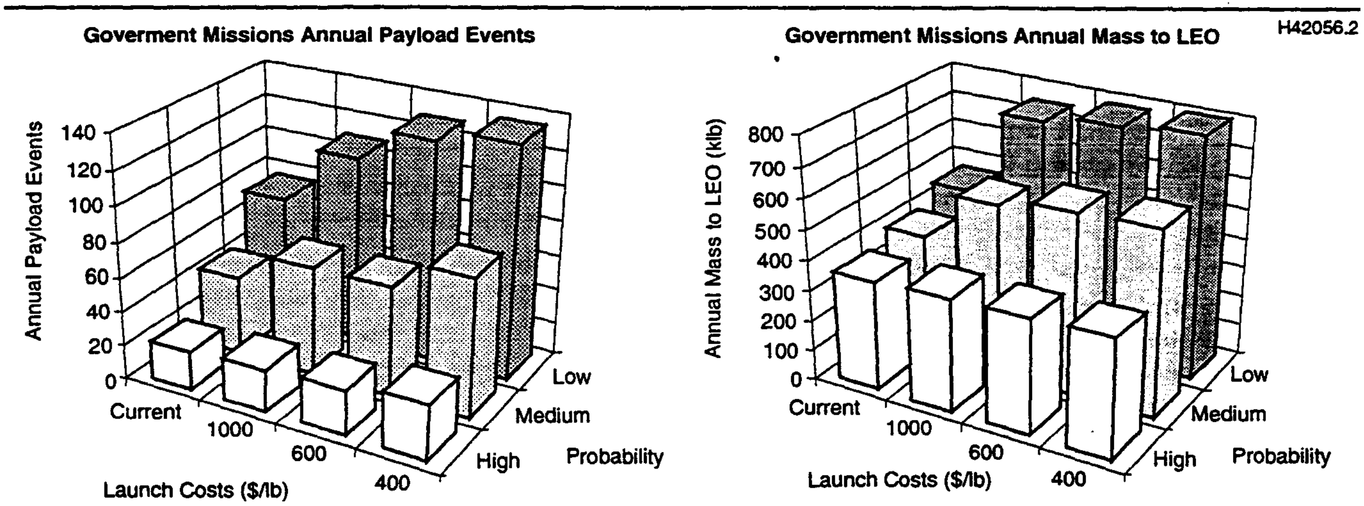

Figure 2-5. The Government Market Has an Opportunity for Growth Provided There Is a Significant Reduction in Launch Costs

General Purpose Heat Source transport canisters, and disposal via a soft landing in a crater on the backside of the moon. This relatively low-risk option was cost competitive with the ground disposal option at ground processing costs of \$100/kg and launch costs of \$600/lb or less (Figure 2-6). In addition, lunar deposit offers near permanent disposal (approximately 100,000 years) versus the temporary nature of terrestrial disposal.

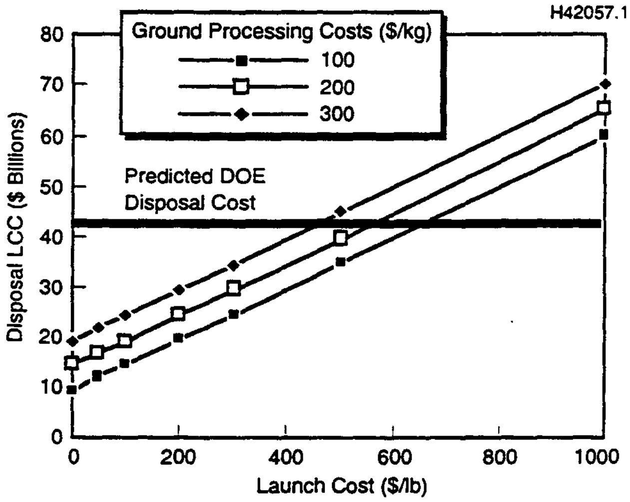

Figure 2-6. Sensitivity of Space Disposal of Nuclear Wastes to Launch Costs

2.3.4 Space Business Park/Tourism

The space business park/tourism market is the initial extension of commercial manufacturing and tourism into space. It is a synergistic combination of the rapidly expanding high technology computer chip and biomedical research industries with revenues approaching \$250 billion per year, plus the terrestrial-based tourism market with US revenues currently exceeding \$350 billion per year. These markets are combined to take advantage of a common pressurized facility and logistics transportation to low Earth orbit (LEO). The approach of combining the industrial and tourism markets allows these markets to be viable at launch costs of \$600/lb.

The market potential for both microgravity processing and space tourism appears to be encouraging if space transportation costs can be significantly lowered and airline-like services offered. As shown in Figures 2-7 and 2-8, the traffic in experiment lockers and people worldwide increases exponentially as the ticket price drops. For example, if a trip into space costs \$30,000, there is a reasonable chance (medium probability) that over 10,000 people would buy tickets annually.

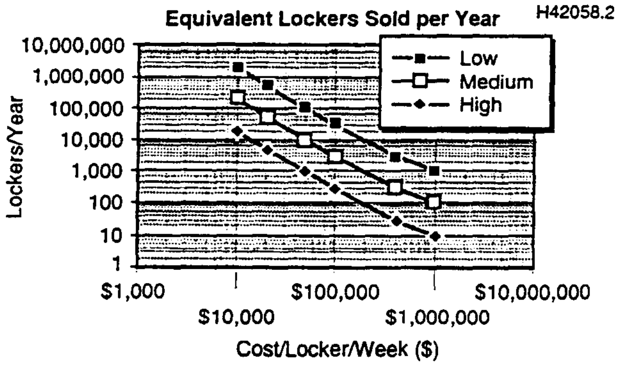

Figure 2-7. Microgravity Processing Demand

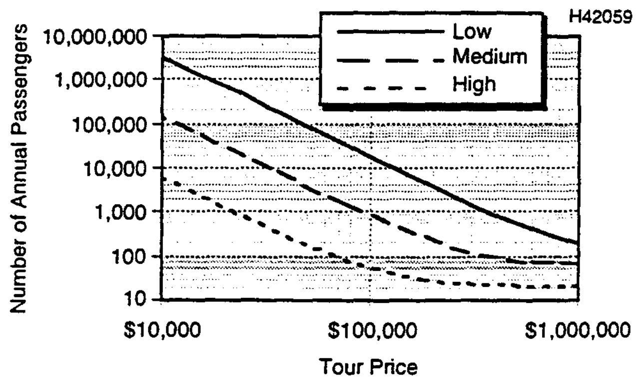

Figure 2-8. Tourism Demand

2.3.5 Other Potential Markets

Space Manufacturing/Processing. There is currently very little significant commercial interest or business activity in the space manufacturing/processing area because the practical demonstration of space manufactured products simply has not yet occurred on a commercially significant scale. Shuttle based access to space is useful for experimental purposes but is incompatible with commercial practices. Based upon market contacts, a "preferred" system for space access would provide 30 to 90 days on orbit, provide high levels of dedicated processing electrical power, operate autonomously without continuous astronaut attendance, and provide schedule compliant and routine airline type access service with elimination of bureaucratic impediments.

It is reasonable to assume that these experimental and research programs will result in breakthrough technology that will demonstrate the potential of significant commercial returns and therefore stimulate greater commercial involvement.

The elasticity of demand for the space manufacturing/processing market was estimated from responses derived via direct interface with potential users and is shown in Figure 2-9. A cost value corresponding to Spacehab was taken as a commercial access baseline.

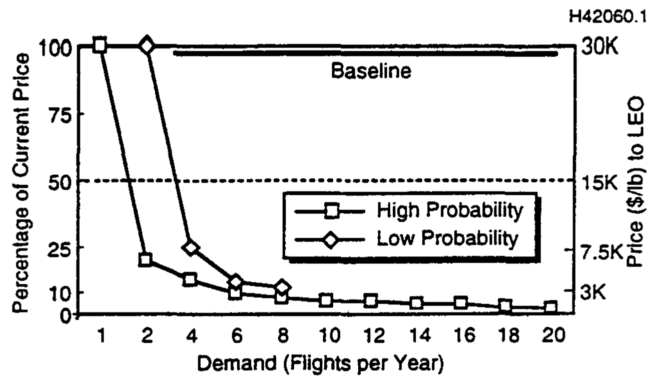

Figure 2-9. Space Manufacturing/Processing Elasticity of Demand

As shown, commercial demand would still be small even if the cost were reduced by 50%. A reduction to 25% of current costs would result in a two to four times increase in demand. A reduction to 10% indicated an increase in demand approaching tenfold; while a dramatic reduction in price to 1% showed an increase in demand by a factor approaching 20. The indicated net result was that the differential reduction in price exceeded the corresponding differential increase in demand, therefore demonstrating an elasticity of demand of less than unity. This market may merge into the space business park.

Remote Sensing Market. Space remote sensing is a growing market poised for rapid expansion in commercial applications over the next 5 to 10 years. Several US companies have announced plans to deploy their own constellations of remote sensing satellites, with 1- to 20-meter resolution, during the late 1990s. The forecast of revenue to be generated from space sensing appears to be sufficient to support several commercial operators. Annual sales are expected to increase from $332 million in 1995 to $823 million by the year 2000. As this market matures and diversifies early next century, there will be a substantial increase in demand for space imagery. The longer term outlook indicates the market could reach $2.7B in 2005, rising to $6.8B by 2010.

At today's launch prices, the growth in the number of remote sensing satellites deployed will be moderate. Commercial satellite deployments will build up to an average of three per year by the end of this decade; replacement and growth satellites will push the average to four per year by 2005 and to six per year by 2010.

If a new commercial space transportation system were introduced with only a small reduction of today's launch price, a commercial company would not deploy more remote sensing satellites than they currently have planned. At 50% of today's price, the research data indicated that a company would launch two satellites instead of one, as illustrated by the high probability of occurrence curve in Figure 2-10. The deployment estimate increases to four for the low probability curve.

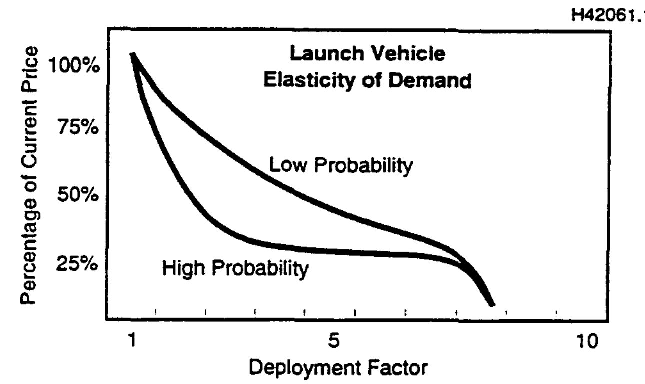

Figure 2-10. Remote Sensing Launch System Elasticity

The threshold price at which launch vehicle demand becomes elastic is estimated at 30% of current price for the high probability demand curve. For the low probability curve, demand is elastic at approximately 75%. At either of these percentages, commercial remote sensing satellite companies will double their planned launch purchases. Demand becomes inelastic again, however, below approximately 25%. Within the elastic range, the commercial remote sensing companies would increase their purchases by a factor of two to six times, depending upon the price selected by the launch provider.

Assuming that a new commercial launch system were introduced at 50% of current launch price, there is a high probability that the total of four commercial launches forecast in 2005 would increase to eight. The figure also indicates that at the 25 to 30% range, the total number of launches would increase to 24 for either the low or high probability curve.

2.4 MARKET CAPTURE ANALYSIS

2.4.1 Methodology

In order to assess the portion of the aggregate market garnered by a new commercial launch system and assess potential revenue that would result, a capture analysis was performed. Figure 2-11 shows the flow for the capture analysis process.

First, mission models were developed from the market elasticity curves for specific launch costs (in terms of $/lb LEO equivalents) and each probability of occurrence. (See Figure 2-12 for the aggregate elasticity curves.) The launch costs were selected based upon significant thresholds in the demand elasticity

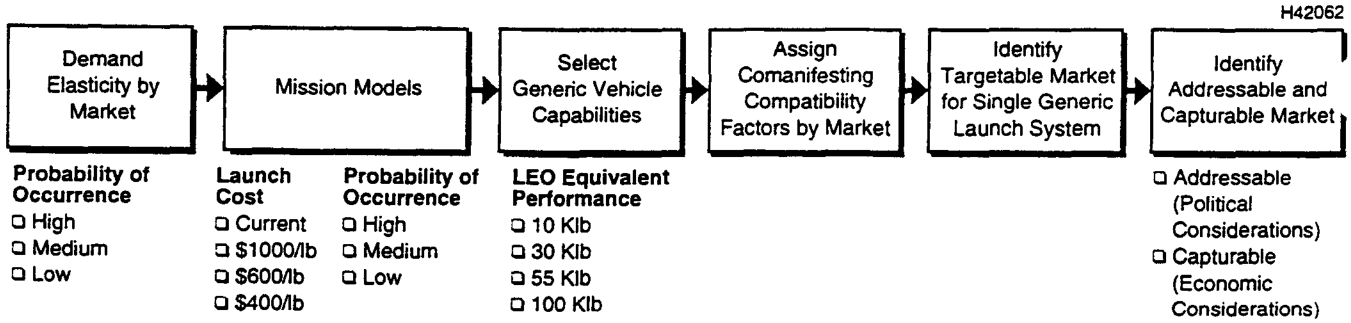

Figure 2-11. CSTS Mission Capture Methodology

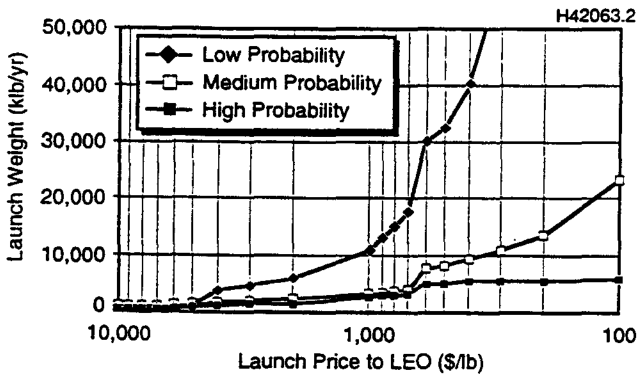

Figure 2-12. Aggregate Market Elasticity as a Function of Reduced Launch Costs

curves. The following threshold values were chosen for analysis:

- $1000/lb—The high probability market doubles the mass to orbit over current levels.
- $600/lb—Several new markets emerge at this level (all probabilities).
- $400/lb—New and traditional markets experience significant growth.

Figure 2-13 highlights the influence of the various individual markets at the threshold values identified for the time period 2005-2014. At $1000 per lb, communications and government missions occupy a majority of the demand, i.e., about 80%. At $600 per lb, space business park and hazardous waste emerge, the latter as a very significant portion of the market. There is the potential for 4.5 million pounds being delivered per year, which represents a significant growth over existing equivalent Earth-to-LEO traffic. At $400 per lb, communications and the space business park exhibit dramatic growth. Reducing launch costs to $100/lb would result in additional market expansion, but was not considered herein.

Four specific launch vehicle capabilities were selected to be used in the analysis. These launch vehicle equivalent LEO payload sizes were 10,000 lb, 30,000 lb, 55,000 lb, and 100,000 lb. LEO equivalent mass encompasses both the payload and any additional stages and/or propellant to deliver the payload to its operational destination.

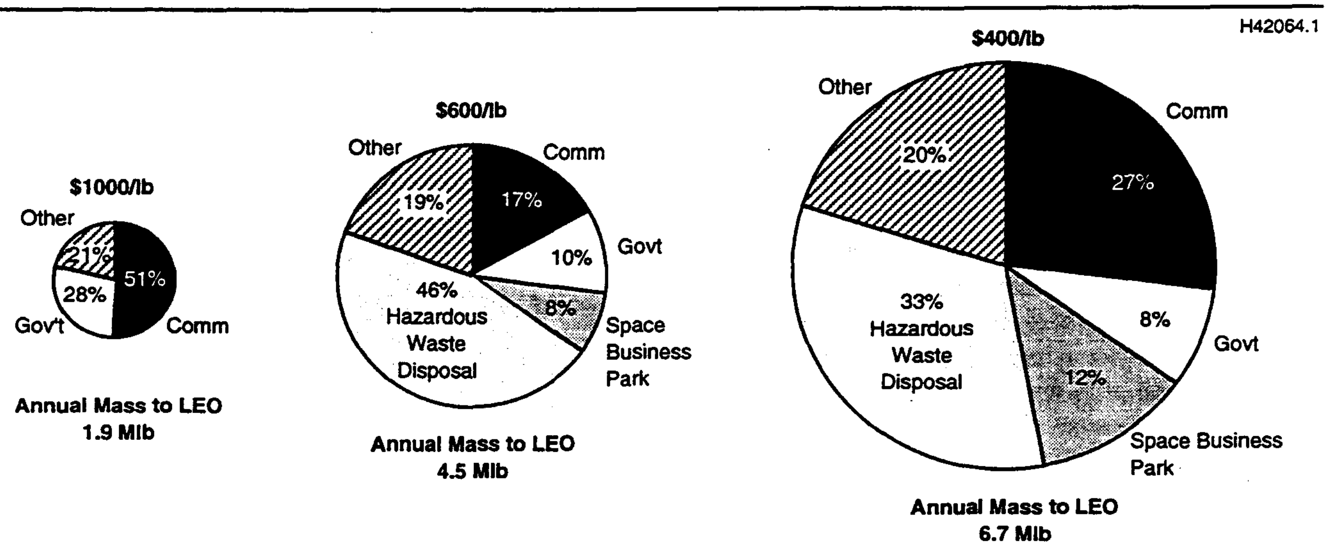

Figure 2-13. Market Distribution Perspective—Medium Probability

Flight rates were based upon four considerations: co-manifesting of payloads, vehicle size, political impediments to open competition (and capture), and competitiveness relative to existing and near-term systems. Co-manifesting of payloads was allowed up to a level deemed appropriate for the particular market area. For example, co-manifesting of mobile communication satellites was limited by orbital plane and ascending node separation considerations.

Compatibility between the projected missions and the notional launch vehicles was assessed next. This downselection of the mission model was considered the "targetable market."

It was also recognized that some traditional space missions (space science, communications, remote sensing) would continue to fly on launch systems offered within the country of origin unless dramatically lower launch prices were offered. Thus a politically driven subset market emerged, an "addressable market" in which CSTS could actually compete.

The capture for each addressable market was based upon the price of a new commercial launch service relative to existing prices. This subset is the "capturable market." At current prices, a new system could not be expected to capture more than 15% of the market. At around $1000/lb, capture would rise to about 80%. At $600 to $400 per lb, it was assumed that a new system could capture the entire addressable market.

2.4.2 Results

The results of the market capture analyses for the medium probability market are displayed in Figure 2-14. The data are displayed as average number of flights per year for the time period of 2000 through 2030. At current launch prices, a new system will not capture more than 10 flights per year, because there is a smaller market at that launch price and a new system would experience tough competition from existing launch vehicles.

At significant reductions in launch costs, however, the market projections show significant increased demand for launch services. Then greatly reduced cost for access to space will not only stimulate existing and planned markets, but will also enable new markets.

For example, at a delivery cost of $600 per lb, launch demand of between 50 and 100 flights per year is generated for all but the largest vehicle size, with a high capture ratio predicted. Even more dramatic levels are possible at $400 per lb, i.e., over 250 flights per year with a 10,000-lb vehicle and over 150 flights per year with a 30,000-lb vehicle.

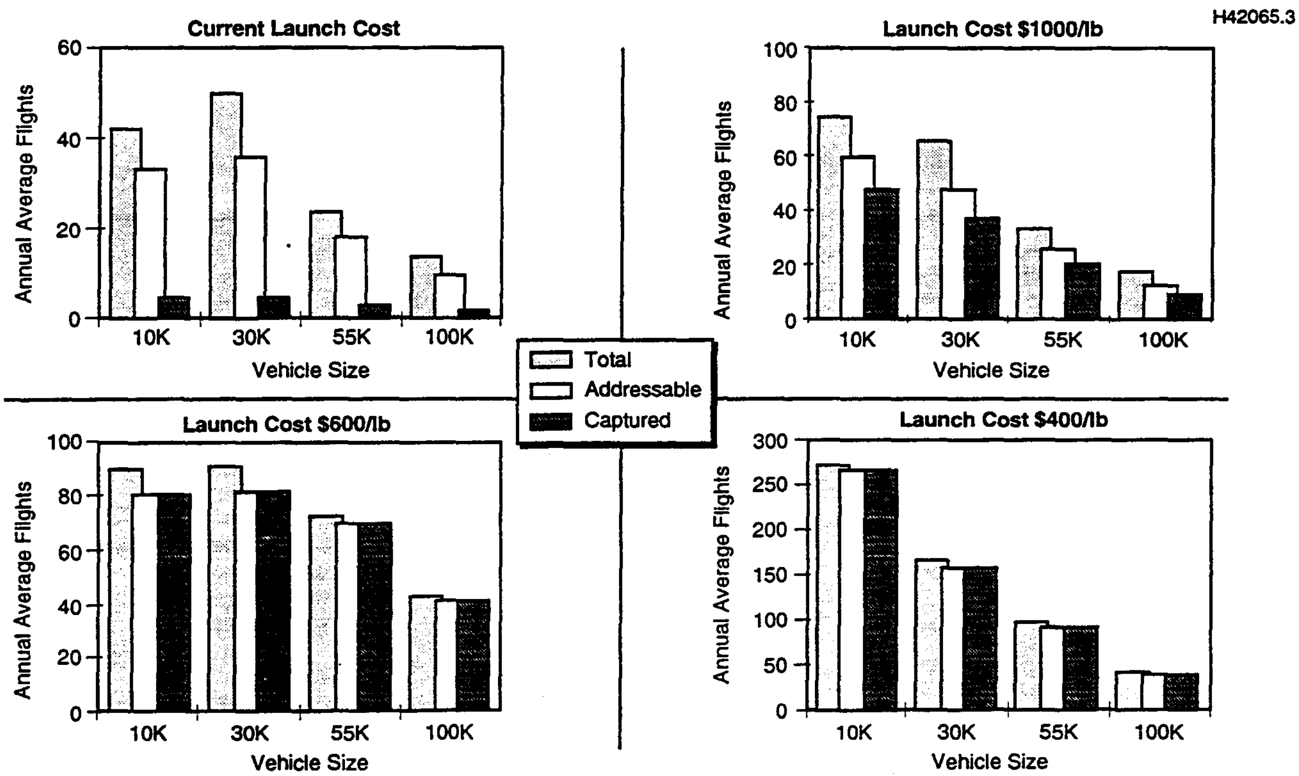

Figure 2-14. Targetable, Addressable, and Capturable Markets—Medium Probability

2.5 REQUIREMENTS AND ATTRIBUTES ASSOCIATED WITH THE CSTS MARKET BASE

Early identification and definition of system attributes and requirements are essential to ensure that the transportation system meets the needs of the users. A preliminary database of attributes and requirements, essential for all future concept development work, has been developed based on the data gathered during the market evaluation and analysis activities.

These CSTS attributes represent key design goals toward which the system must be directed. Some of the common attributes in the database are shown in Table 2-1.

Many market areas have provided enough detail such that attributes can begin to evolve into system-level requirements. Advanced booking time values, for example, were provided by most of the market areas. Booking time is defined as the time (in months) between the request for a launch and the actual launch.

A graphical analysis (Figure 2-15) indicates that the system requirement should be somewhat below 18 months, substantially lower than many current systems. There is a trend toward routine scheduled flights as opposed to unique chartered flights. The data illustrate that a 6-month requirement would capture 77% of the markets and 90% of the potential revenue at either $1000/lb or $400/lb. At the lower system cost of $400/lb, more time-driven applications enter the market, and the system becomes more sensitive to the selected booking time requirement. Thus, it becomes more important to minimize the requirement.

Sensitivities, similar to the booking time analysis, are essential in making informed decisions regarding the selection of requirements; they make important contributions to the point of departure database, which will be used in further market, business and technical evaluation activities.

Table 2-1. Relative Importance of System Attributes to Key Market Areas

System attributes	Key market areas: Comm	Government missions	Hazardous waste	Business park
Minimum booking time	M	M	L	H
Launch on need	H	H	N/A	H
Launch on schedule	M	M	M	H
High launch rate	L	M	H	H
High reliability	H	H	H	H
Simplified launch operations	H	H	H	H
Standardized payload interface	H	H	H	H

H = Essential for market area existence M = Important for market area
L = Minimal requirement for market area N/A = No requirement for market area

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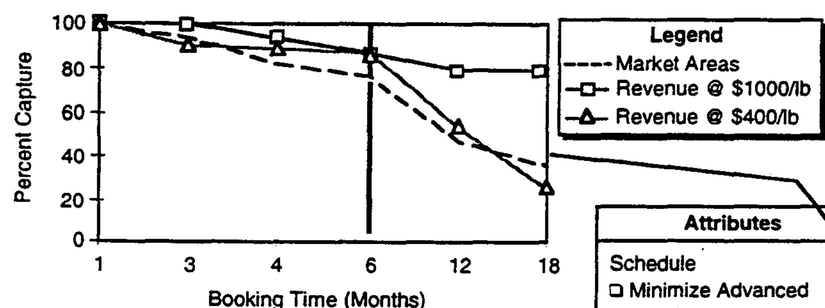


Attributes	Requirements
Schedule ❑ Minimize Advanced Booking Time	❑ ≤ Six Months • Booking Times of ≤ 6 Months Captures: — 90% of Revenue — 77% of Markets
Dependability ❑ High Probability of Launching on Schedule	❑ ≤ Five Days • Launching Within 5 Days of Scheduled Date Reqd Captures: — 80% of Revenue — 60% of Markets

Figure 2-15. CSTS Requirements Sensitivity Analysis

Section 3
BUSINESS ANALYSIS

The objective of the business analysis was to develop decision criteria based on the target markets, the business risks, and the potential of realizing a return on the investment. The analysis was initially intended to show the return on investment (ROI) of a space transportation system that was developed from a purely commercial standpoint. However, rather than focusing upon the financial viability of a specific concept, the analysis was targeted at developing the bounds of parametric conditions with regard to the financial feasibility of any commercial system.

3.1 METHODOLOGY

Using the market survey results from section 2.3 and the market capture analysis in section 2.4, an estimate of the average annual revenues was calculated for transportation systems of differing payload capabilities and launch prices. Using these data and common financial guidelines, the payback cash flow required per flight was determined for differing levels of initial investments. Differing mechanisms of investment risk mitigation to achieve these financial conditions were explored. The overall methodology is illustrated in Figure 3-1.

3.2 ASSUMPTIONS

Some basic guidelines were needed for the business analysis for the transportation system. It was assumed that the nonrecurring investments required to bring the system to an initial operational capability would be five years from program go-ahead. This time span would allow for the required design and engineering, prototyping, testing, facility development, and initial production. The total funding required for the development was distributed as follows: 10% in the first year, 20% in the second year, 30% in the third and fourth years, and 10% in the fifth year. The mission model profile assumed was a 3-year ramp to the steady-state demand level, with a 25% capture in the first year of operation, 50% the second year, and 100% capture in the third and subsequent years (to the appropriate capture percentages as a function of vehicle delivery price). The maximum allowable period over which to recover the investment was set at 10 years.

Other significant assumptions involved the time value of money and tax implications. Constant year 1993 dollars were used in order to preclude the effects of inflation. The cost of capital was assumed to be fixed at 8% per year. Tangible assets of the transportation system would be depreciated over a 7-year period beginning with the first year of operation. The marginal federal tax rate was assumed to be fixed at 34%.

3.3 RESULTS

At the present time, the space transportation market is considerably different from other (non-space) commercial markets. Launch infrastructure, principal launch assets, and manufacturing facilities are under the ownership and control of various branches of the US government, with the market predominately determined by government budgets. This introduces a large element of market risk due to the uncertainties of annual appropriations. Transitioning to a market which is predominately commercial requires the development of new markets and a major cultural change in the ways of doing business in space.

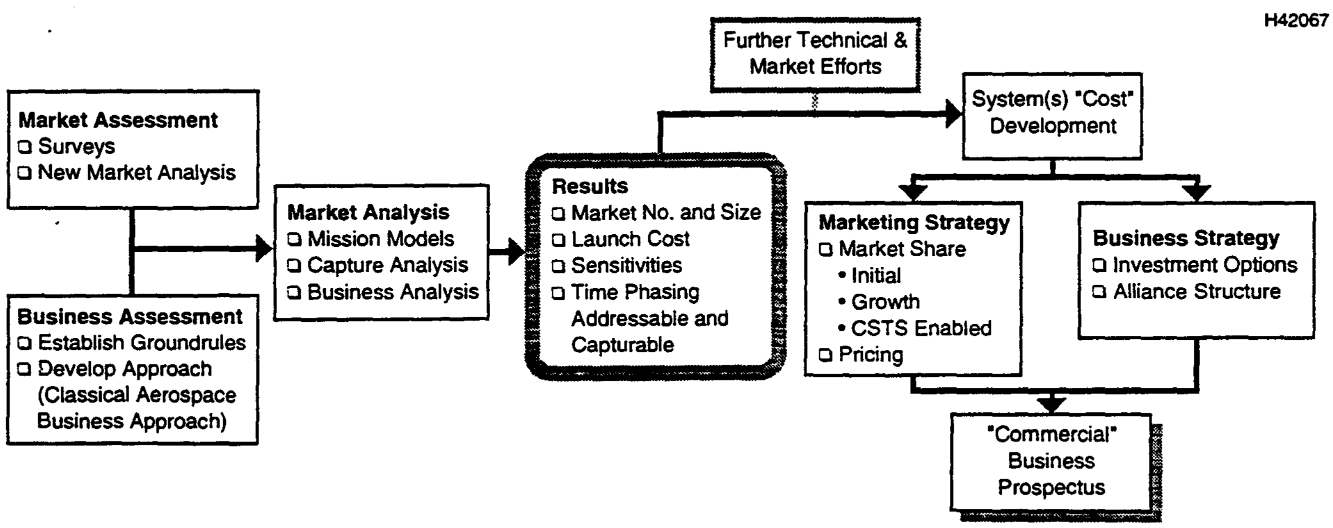


Figure 3-1. Business Analysis Methodology

Private investment in space transportation can be a feasible venture only if the investors can be repaid in a reasonable time and at a reasonable rate. The revenues from each flight, based upon the payload capability and the price per flight, must be balanced against the recurring (operating) cost charged to that flight, repayment of the investment debt incurred in constructing the system, and some amount of return to the commercial investors. Figure 3-2 displays the relative minimum annual revenues (averaged over 30 years) derived from the mission capture model for the medium probability model.

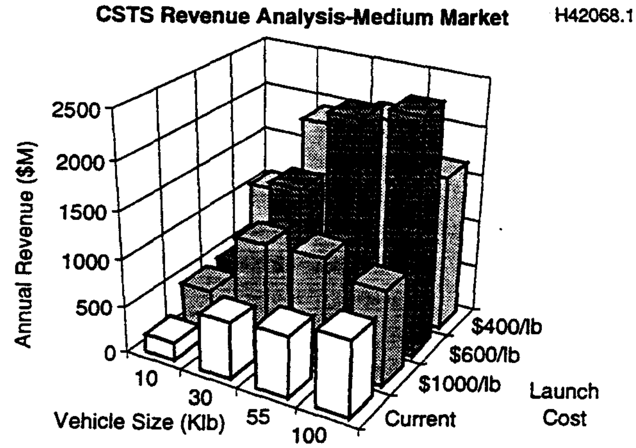


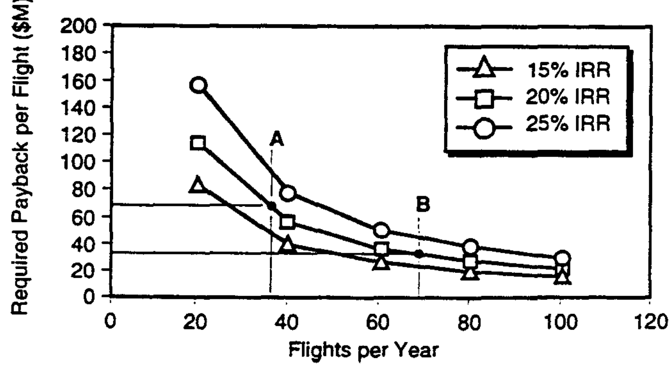
Figure 3-2. Minimum Revenue Potential for Medium Probability Model

One measure of success is the internal rate of return (IRR). An IRR of 15% to 25% over the first 10 years of operations has been selected as the target range to evaluate commercial feasibility.

Figure 3-3 depicts a scenario wherein a commercial space transportation system was developed for a $5 billion investment. The figure shows the payback cash flow per flight required to satisfy a given IRR goal. It also shows as an overlay the resulting flight rates from the mission capture analysis at different launch prices and vehicle payload capabilities (Figure 2-14). As an illustration using the figure, in Case A, a vehicle with 30,000-lb payload capability in the medium probability model, priced at $1000 per pound, will capture 38 flights per year. This system must achieve a payback cash flow of about $70 million per flight in order to service its debts and yield a 20% IRR after 10 years of operations. However, at $1000 per pound, a 30,000-lb capability system realizes only about $30 million in revenues, even before subtracting recurring costs of operation! Obviously, such a scenario is not economically viable.

In another example, Case B, a vehicle with 55,000-lb payload capability priced at $600 per pound can capture 70 flights per year. It must achieve a payback cash flow of about $35 million per flight in order to service its debts and yield a 20% IRR after 10 years of operations. At a price of $600 per pound, the 55,000-lb capability system can realize about $33 million in revenues per flight. This case shows that if investors were able to accept a reduced IRR it might be possible to attain an economically viable payback. These examples indicate that launch price reductions must reach an order of magnitude to approach financial payback targets.

Looking at the situation another way, Figure 3-4 can be used to illustrate how this level of payback cash flow can be used to show the maximum possible investment. Referring again to Case B, the 70 flights per year of the 55,000-lb payload capability launch system priced at $600 per pound would generate about $2.31 billion in annual revenues. From this annual revenue, the operating costs must be subtracted to determine the annual payback cash flow. Assuming for the moment the annual operating costs were zero, the $2.31 billion annual payback cash flow would almost support a $5 billion investment at 20% IRR after 10 years of operation. However, if annual operating costs were one half the transportation price charged, then only $1.2 billion would be available for the payback



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Current Price to LEO		
Vehicle	High	Med
10K	3 Flts	5 Flts
30K	4 Flts	5 Flts
55K	2 Flts	3 Flts
100K	1 Flts	2 Flts

$1000/lb to LEO		
Vehicle	High	Med
10K	32 Flts	48 Flts
30K	28 Flts	38 Flts
55K	15 Flts	21 Flts
100K	8 Flts	10 Flts

$600/lb to LEO		
Vehicle	High	Med
10K	54 Flts	81 Flts
30K	43 Flts	82 Flts
55K	41 Flts	70 Flts
100K	25 Flts	41 Flts

$400/lb to LEO		
Vehicle	High	Med
10K	241 Flts	269 Flts
30K	102 Flts	161 Flts
55K	45 Flts	95 Flts
100K	27 Flts	41 Flts

Figure 3-3. Payback Per Flight Required With a $5 Billion Investment

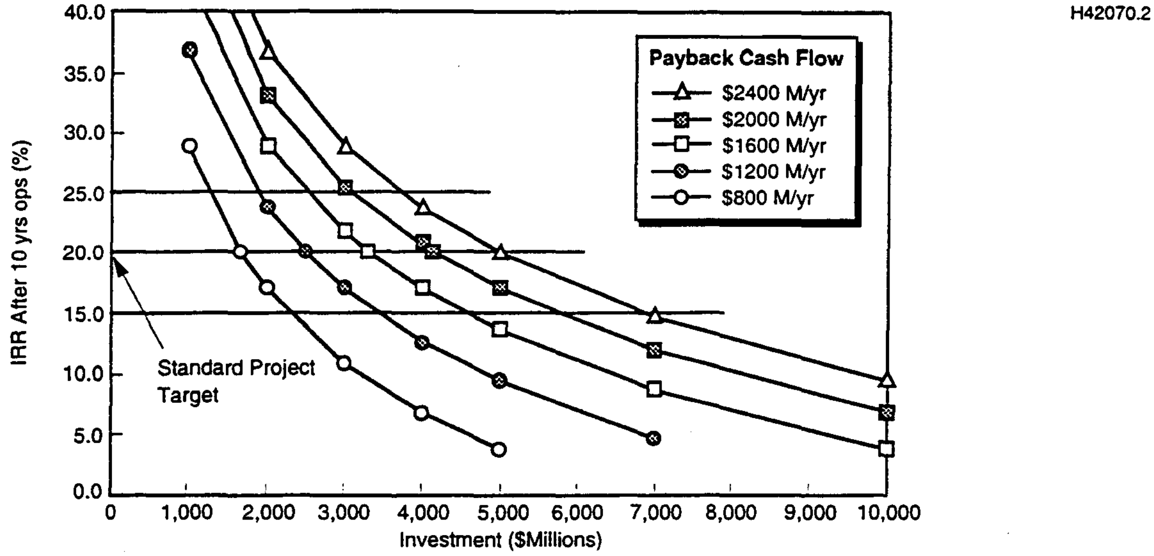

Figure 3-4. IRR Sensitivity to Payback

cash flow. This would support an investment of only about $ 2.5 billion at the 20% IRR.

The study to date did not address the predicted cost of space launches or the technical requirements to achieve these specific launch cost goals. However, this analysis indicates that as a commercial investment measured at standard industrial investment return levels, the investment cost for a new space launch system must be kept in the range of a few billion dollars.

This points out a potential paradox in the commercial space transportation market. Low prices are necessary to attract more users; potential reduced prices reduce the revenues; consequently, the cash flow available for investment payback is reduced.

The results of the market analysis conducted herein have not been able to show that the commercial space market is elastic enough to enable the revenues per flight to meet the combined payback and operations costs for a completely commercially developed system.

To attract commercial investment it appears that some level of government participation will be necessary. There are different options which can be considered for this, ranging from government development and commercial operation (which reduces the investment cost) to market and loan guarantees (which reduce the uncertainty in the revenues). Other options, including corporate tax incentives and innovative financial arrangements, may also be considered. Some of these investment options are outlined in Table 3-1, along with some statements regarding the advantages and disadvantages of each option.

3.4 SUMMARY

The business analysis for this initial phase of the CSTS has been used to define the economic thresholds associated with a commercially viable system. The CSTS specifically did not analyze the cost and technical constraints on a new space launch system. Parametric data relationships between investment and

Table 3-1. Business/Investment Options

Nonrecurring funding option	Relative advantages	Relative disadvantages
Industry/government sharing	■ Pooled resources ■ Distributes risk ■ Evolutionary change in industry business practices required	■ Dependent on government funding ■ Increased organizational complexity
Alliance members only	■ Reduced organizational complexity ■ Moves aerospace industry closer to a commercial environment ■ Bypasses government funding constraints ■ Reduces government's risk	■ Drastic change in industry's practices and culture required ■ Places all risk on industry's shoulders ■ Total investment requirements exceed industry capabilities
Government only	■ Reduces industry's risk ■ No change in industry business practices required	■ Does not move the industry closer to commercial operations
Seek investors from outside of Alliance and government	■ Moves aerospace industry closer to a commercial environment ■ Bypasses government funding constraints ■ Distributes risk	■ Loss of single point control of the project

t3.1:

payback requirements indicate that a commercial space transportation system may be viable at low investment levels and higher launch rates. To achieve these demanding goals, it appears that joint government/ industry investment into the development of this system will be required. There are many options yet to be examined for this investment and for financial arrangements.

Section 4
RECOMMENDED FUTURE TASKS

It is recommended that further study be conducted in three areas: market research, business strategy, and transportation and architecture.

4.1 MARKET RESEARCH

The fidelity of the database must be refined to include more detailed information on economic, technical, social, and legal issues and concerns for the most promising commercial markets. The added research should focus on increasing the confidence in the mission model over the 2000 to 2030 time horizon (i.e., to accurately define the markets, their potential growth, the size of the markets available to a new commercial launch system, and the share that can be captured by the new launch system). For example, the hazardous waste disposal market requires assessment of the major concerns about the disposal of nuclear waste in space. Also, the credibility of social and legal issues and the intent of responsible agencies, such as the Department of Energy, to consider a new launch system for nuclear waste disposal needs to be reviewed.

4.2 DEVELOP COMPREHENSIVE BUSINESS STRATEGY

A new space transportation system is dependent upon the ability to structure a business plan that shows a financially sound and realistically achievable venture. This plan must address three key elements to achieve this goal: financial, regulatory, and Alliance participation.

Financial. The following types of questions should be addressed:

- What rate of return and payback period are required to obtain support from the financial community?
- Will initial niche markets be used to generate the revenue stream to finance subsequent market exploitation?
- Will different pricing structures be employed for co-manifested operations?

Regulatory. The role of government in defining the liability laws, vehicle qualification and flight worthiness certification, and crew training/certification (if required) must be clearly defined/interpreted.

Alliance Participation. The working relationship within the Alliance and between the Alliance and the government must be developed to ensure the most effective application of assets in developing the system concepts, technology development plans, etc. This may lead to the introduction of new business entities that are specifically chartered to perform this commercial business activity.

4.3 DEVELOPMENT OF TRANSPORTATION SYSTEM AND ARCHITECTURE CONCEPTS

One of the primary objectives of continued study should be to define a commercial launch system, composed of one or more vehicle configurations, to maximize return on investment while meeting market demands.

A recommended approach to conceptualizing a CSTS transportation architecture is based on three fundamental principles:

1. Concepts must support the defined business strategy as well as meet system requirements derived from the market analysis.

2. A two-step concept development process wherein lesser concepts can be screened prior to extensive design activities.

3. Conceptualization of an entire system, not just a vehicle, through allocation of cost, operability, and performance requirements.

Section 5
VISION OF THE FUTURE

An important aspect of the study was the creation of a vision of space transportation's future. This vision can be divided into two distinct, but interdependent elements. The first is the role the system would fill, and the second is the projected evolution of the space marketplace. Together, these two constituents provide a definitive image of the Alliance's perception of the future of space commercialization and the associated high-technology employment.

5.1 ROLE OF A COMMERCIAL SPACE TRANSPORTATION SYSTEM

The evolution of space utilization into a new commercially motivated era is dependent upon the development of a modernistic commercial transportation system. This role is diverse in nature, encompassing many aspects unfamiliar to the conservative culture pervasive in the US space launch industry. The Alliance's view of this new role consists of the four fundamental elements shown in Figure 5-1.

1. **New Market Realization.** As part of the study, a great deal of emphasis was placed on the evaluation of these market areas, and their potentials were found to be intriguing. The introduction of a new, low-cost launch system would enable the realization of these potential markets, discussed in Section 2.

2. **Competitiveness Improvement.** The US launch system industry dominated the international marketplace through the early 1980s. Foreign competition has steadily eroded the US position, now capturing a 60 to 70% share of the commercial launch market. To regain the competitive edge, a new transportation system is required.

3. **Launch Industry Rejuvenation.** The development of a new commercial launch system accomplishes two objectives. First, the US space industry will develop a broader manufacturing base, resulting in lower launch costs to the government. Second, it would enable the US government to partially rely on commercial industry to maintain its technical and experience base in vital areas.

4. **Public Benefits.** A new space transportation system would provide direct and indirect benefits to the general public. The development of new market areas would create new opportunities and capabilities, i.e., space tourism. It enables new markets that create entirely new high-tech jobs and new tax revenues. It would enhance productivity through the employment of space-based assets, e.g., communications and remote sensing. Additionally, the disposal of hazardous waste in space would enhance our management of the Earth's environment. Intangible benefits, more difficult to predict, include increased public support for space related endeavors, and the inspiration of society to accomplish even more difficult tasks.

5.2 EVOLUTION OF THE SPACE MARKETPLACE

The second element of the study's vision is the foreseen evolution of the space marketplace. Figure 5-2 summarizes the high-level attributes of the current and projected future space marketplace. The current space industry is driven by the needs of the government and focuses on the requirements of the military and scientific communities. Launch system and spacecraft development efforts are funded almost exclusively by government agencies and are therefore captive to the politics associated with government-funded programs. Due to the specialized requirements of government agencies and the experimental attitude currently associated with space-related endeavors, the costs of doing business in space are high for both transportation and operation. As a result, the public perceives space as a generally inaccessible resource, only available to government-sponsored programs.

Twenty to thirty years in the future, the Alliance envisions space to be an entirely different enterprise. The Alliance's under-lying desire is for the public to view space as an integral and fundamental part of its

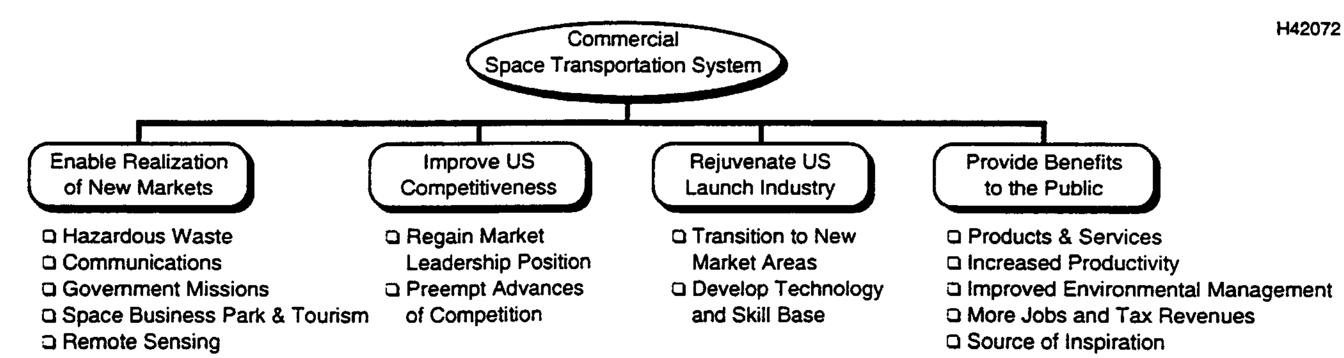

Figure 5-1. The Role of a New Commercial Space Transportation System

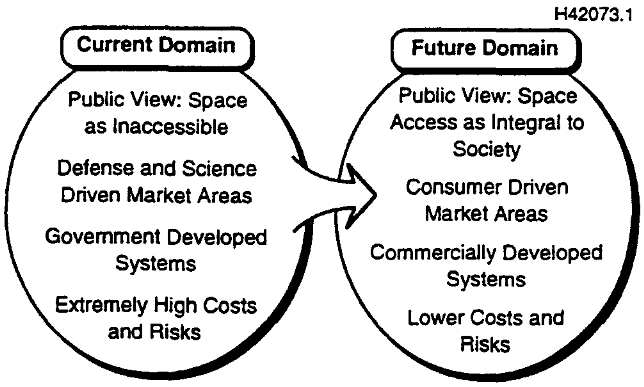

Figure 5-2. The Projected Evolution of the Space Marketplace

existence, communicating globally, using products manufactured in space, vacationing at space-based amusement parks, etc. To attain this vision, changes to the culture underlying the space industry are necessary. The industry must evolve to commercial motivations and aspirations, including the commercial development of space. The government should not be the only source of revenue for space programs. The industry should eventually transition from a defense and scientific driven enterprise to a consumer driven one. Lowering the cost of access to space is essential to the ultimate realization of this transformation and would be the top priority of the Alliance.

5.3 SUMMARY

In many respects, the study revealed bright prospects for future development and expansion of space markets. While government missions are projected to continue at present or modestly increased levels, commercial market growth is expected to be substantial, eventually dominating the total market. The rate of this growth and its magnitude are dependent upon just how much the cost of space transportation can be reduced.

However, for the most conservative, high probability market projections, it was found that the revenue potential would not be sufficient to support the commercial development of a new transportation system. For the nominal, or medium probability market, the financial outlook improves to the point that, while a commercial investment would not be recovered within traditional financial guidelines, a cooperative venture, sponsored jointly by the industry and government, may be feasible. Uncertainties in market and business estimates prevent us from reaching definitive conclusions. Yet the potential rewards o such a venture, not only financially but for the benefit of the nation as a whole, are great enough to warrant further investigation.

Numerous approaches must be explored toward cooperative government/industry investments, some of which have been used in the past and are proven, and others which are less conventional, reflecting new ways of doing business. These approaches should be explored to understand which might best serve the interests of the country and the needs of private industry. The scope of such an activity should include not only financial considerations, but also respective roles and responsibilities, organization and management approaches, legislative and liability issues, and strategies for program accomplishment.

It is further recommended that these subjects be addressed by a working group comprising representatives of the industrial Alliance and government agencies, including NASA, Departments of Defense, Commerce, Energy and Transportation, and Office of Management and Budget.

Finally, the Alliance recognizes that considerable discussion and debate are now under way nationally concerning a next generation transportation system in general, and in particular, the single stage to orbit concept. Some commentary on this, as it relates to the findings of the Commercial Space Transportation Study, is in order.

The future space transportation system selected must be responsive to commercial user requirements in addition to those of government users. While low operating cost is fundamental, other parameters, such as launch dependability, higher reliability, very short booking time, and user friendliness, are of equal importance. Another commercial requirement that will eventually emerge is the ability to accommodate the general public (in space flight) without rigorous astronaut-type training. These varied requirements and system capabilities must be introduced into current technology development plans. Unless the next space transportation system satisfies these needs, that system will not be widely used commercially.